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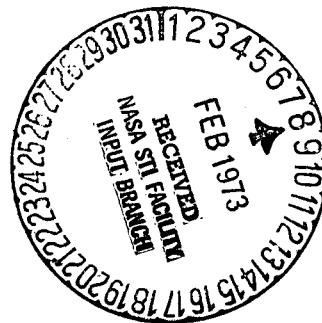
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INVESTIGATION OF THE PHOTOGRAPHIC CHARACTERISTICS OF
UFSH-4 FILM USED IN THE "ORION" EQUIPMENT

V. M. Uvarova, M. R. Shpol'skiy, A. N. Oshurkov,
Dzh. B. Oganessian, N. V. Uvarova

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INVESTIGATION OF THE PHOTOGRAPHIC CHARACTERISTICS OF
UFSh-4 FILM USED IN THE "ORION" EQUIPMENTV. M. Uvarova, M. R. Shpol'skiy, A. N. Oshurkov,
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ABSTRACT. Adequately sensitive film of the UFSh-4 type, with high resolution capacity, has been used in the range of wavelengths 4000-1800 Å to obtain spectrograms of particular stars with the help of the "Orion" orbital observatory. The possibility of prolonged orbiting of this film in the conditions of outer space (over two months) has been established. The sensitivity of this film has practically remained unchanged over the past period despite the heavy fogging formed (with a density of about 0.8-0.9). No appreciable changes in the physicochemical characteristics of the emulsion layer of the above film have been discovered.

Photographic materials sensitive to shortwave ultraviolet radiation are /42* extensively used in different fields of science and technology.

Specialists at the Gosniikhimfotoprojekt [State Scientific Research Institute of Chemical Photographic Projects] have developed a number of photographic materials for registering the entire short-range part of the spectrum shorter than 3000 Å, including the region of short X-radiation [1-3]. These photographic materials have been successfully used in rocket experiments for studying solar ultraviolet and soft X-radiation [4-6].

Photographic characteristics of UFSh-4 film. UFSh-4 photographic film was used in the "Orion" spectral astrophysical apparatus designed for investigating the shortwave radiation of stars. This film has a quite good sensitivity in the wavelength range 4000-1800 Å and a high resolution ($R = 130$ lines/mm in the visible spectral region). Here it should be pointed out that in the UV spectral region film resolution is far higher and is governed by the fact that UV radiation is very intensively absorbed by a photographic layer and reflection from silver halide microcrystals is very small (not more than 10-15%).

The UFSh-4 photographic film has a high concentration of silver halide in the layer. In addition, part of the gelatin in the photographic layer is replaced by other substances for improving the physicochemical properties of the

* Numbers in the margin indicate pagination in the foreign text.

photographic layer. The latter circumstance is necessary for photographic materials used in a deep vacuum: the photographic layer must withstand presence and rewinding in a vacuum of about 10^{-9} mm Hg without impairing intactness of the emulsion layer. The "Orion" apparatus used UFSH-4 film (emulsion No. 59) 16 mm wide on a triacetate base.

The absolute sensitivity of the UFSH-4 film in the wavelength region $4400-2500 \text{ \AA}$ was determined at the State Optical Institute using a FSR-9 spectro-sensitometer. In the spectral interval $4000-2500 \text{ \AA}$ it was virtually constant and was 0.3 erg/cm^2 with a blackening density $D = 1.0$ and $0.06-0.08 \text{ erg/cm}^2$ with $D = 0.3$. An EM-7 electron microscope and the charcoal replicas method were used in measuring the mean size of the emulsion microcrystals ($d \approx 0.7 \text{ \mu m}$) and the density of packing of microcrystals per unit surface of emulsion layer was determined. It was $\sim 2.5 \cdot 10^8$ microcrystals per 1 cm^2 . Using these data it is possible to determine the mean quantum sensitivity of a single microcrystal n_{mc} from the expression

$$n_{mc} = 6 \cdot 10^{11} \frac{H_{\lambda}}{h\nu \cdot N},$$

where

H_{λ} is the exposure in erg/cm^2 ;


$h\nu$ is quantum energy in electron-volts;

N is the number of microcrystals per 1 cm^2 of photographic layer surface.

During prolonged presence in the "Orion" apparatus the UFSH-4 photographic film could be subjected to irradiation by charged particles and gamma radiation. Accordingly, we first determined the influence of radiation on the sensitometric characteristics of the UFSH-4 photographic film. The film samples were irradiated by different doses of gamma radiation from a Co^{60} source, after which they were exposed in an ISP-22 spectrograph (radiation source - PRK-2 mercury quartz lamp). Photographic processing of the film was in a D-19 developer at 20°C for five minutes. The sensitometric characteristics of the films found as a result of the measurements are given in Table 1.

The data in Table 1 show that the sensitivity of the photographic layer and the contrast coefficient remain virtually constant despite an increase in the irradiation dose from 0.3 to 3 rad. It was impossible to measure S and γ due to the strong background fog.

TABLE 1. CHARACTERISTICS OF PHOTOGRAPHIC PROPERTIES OF UFSh-4 FILM

Photographic characteristics	Doses in rads								
	0	0.3	0.5	0.75	1.0	1.5	2.0	3.0	5.0
$S\lambda = 2400 \text{ \AA}$ relative units	5.8	5.5	5.5	5.5	5.5	6.0	6.0	6.0	-
λ	1.4	1.4	1.4	1.4	1.4	1.4	1.3	1.3	
D_0	0.09	0.14	0.16	0.22	0.28	0.34	0.42	0.54	0.92

The radiation stability of UFSh-4 film is evidently caused by the following two factors:

1. the background fog is distributed throughout the entire thickness of the emulsion layer, whereas an image is formed under the influence of UV radiation in only one or two elementary layers of microcrystals;

2. the emulsion layer of the UFSh-4 film contains a considerably greater number of microcrystals than ordinary photographic materials and therefore the loss of some of the emulsion microcrystals in the background has virtually no effect on sensitivity of the photographic layer.

Photographic processing of UFSh-4 film exposed in "Orion" apparatus. A preliminary inspection of the standard films present for two months in the "Orion," that is, under conditions of a deep vacuum, revealed that the emulsion layer was undamaged and did not peel off from the base. There was also no mechanical damage in the punched openings after rewinding under experimental conditions. In order to determine the density of the background fog forming as a result of exposure to ionizing radiation we carried out tests of unexposed segments of standard film. At the same time we tested UFSh-4 film stored in the archives.

Samples of film (standard and archival) were processed in a D-19 developer at different times. The temperature of the developer was 20°C. Below, in Table 2, we give the data collected on fog density on a UFSh-4 film (emulsion No. 59).

The data in Table 2 show that standard film has an extremely high fog of about 0.9-1. The fact that the fog on archivally stored film remained virtually unchanged makes it possible to conclude that the fog on the standard film was caused by background radiation.

TABLE 2.

Duration of development in minutes	Archival film	Standard film
	D_0	$D_0 + D_{bf}$
3	0.09	0.80
4	0.10	0.92
6	0.12	1.18
8	0.15	1.45

Comparison of the data cited in Tables 1 and 2 indicates that the standard films were irradiated with a total dose of about 5 rad. Accordingly, the question arose of decreasing the fog density on the standard films, possibly without changing the sensitivity of the photographic layer.

A decrease in fog density can be accomplished by two methods: reduction of the duration of development and introducing an antifogging substance, benzotriazole, into the D-19 developer. /45

A shortening of development time to three minutes led to some decrease in fog density (from 0.92 to 0.8) without a decrease in sensitivity of the photographic film. Benzotriazole, introduced into the D-19 developer, reduces background fog considerably more effectively. However, there is some decrease in sensitivity of the photographic layer in this case (by ~ 30%).

Table 3 gives the collected data: dependence of photographic characteristics of UFSH-4 film on photographic processing conditions.

Since the absolute radiation fluxes from the registered celestial sources were not known, the standard UFSH-4 photographic film was developed in standard D-19 developer for three minutes at 20°C and without an admixture of benzotriazole.

On the basis of the above facts the following conclusions can be drawn.

1. UFSH-4 photographic film withstood presence and rewinding in open space for a period of two months in the "Orion" spectral apparatus without an appreciable change in the physicomechanical characteristics of the layer.
2. Despite the presence of a strong background from ionizing radiation, sensitivity of the photographic film to UV radiation remained virtually constant.

TABLE 3

Developer	Development time, in minutes	Archival film			Standard film		
		D_0	$S_{0.3}$ relative units	γ	D_0	$S_{0.3}$ relative units	γ
D-19	2	0.1	4.0	1.5	-	-	-
	3	0.1	6.0	1.5	0.9	-	-
	4	0.1	6.0	1.8	1.0	6.0	2.5
D-19 + 15 ml of benzotriazole	4	-	-	-	0.8	4.5	1.6
D-19 + 30 ml of benzotriazole	4	-	-	-	0.4	1.0	0.8

3. In later experiments with films for registering UV radiation, when they were simultaneously subjected to irradiation by ionizing radiation, it is possible to recommend use of a D-19 developer with the introduction of benzotriazole for decreasing background density. However, in this case the problem of measurements of the negatives themselves remains open until it is possible to develop a method for the photometric study of films with an artificially suppressed background.

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